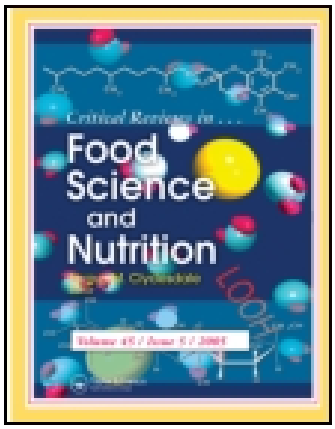

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Portion Size: What We Know and What We Need to Know

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Portion Size: What We Know and What We Need to Know

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There is increasing evidence that the portion sizes of many foods have increased and in a laboratory at least this increases the amount eaten. The conclusions are, however, limited by the complexity of the phenomenon. There is a need to consider meals freely chosen over a prolonged period when a range of foods of different energy densities are available. A range of factors will influence the size of the portion size chosen: amongst others packaging, labeling, advertising, and the unit size rather than portion size of the food item. The way portion size interacts with the multitude of factors that determine food intake needs to be established. In particular, the role of portion size on energy intake should be examined as many confounding variables exist and we must be clear that it is portion size that is the major problem. If the approach is to make a practical contribution, then methods of changing portion sizes will need to be developed. This may prove to be a problem in a free market, as it is to be expected that customers will resist the introduction of smaller portion sizes, given that value for money is an important motivator.

Keywords Bite size, energy compensation, obesity, labeling, packaging, portion size

INTRODUCTION

There is considerable evidence that the portion and packaging sizes of many foods has increased over the last 30 years (Young and Nestle, 2002; Nielsen and Popkins, 2003; Church, 2008; Steenhuis et al., 2010; Piernas and Popkin, 2011) with the concern that this may be one factor that has contributed to the rise in obesity. In fact, it has become received wisdom that an increase in portion size has played a part in the raised incidence of obesity, yet the topic is not straightforward and the resulting advice has often been too certain; failing to reflect the existing state of knowledge and the complexity of the situation. Therefore, existing information, and gaps in our understanding, were both explored.

When considering the control of energy intake and the possibility of obesity, to date attention has been largely directed to physiological and biological events that occur towards the end of a meal; those that stop food intake. The physiological approach has found postingestive mechanisms at a molecular and cellular level that associate the storage of fat with changes in feeding behavior (Morton et al., 2006). Yet, food intake is often controlled more by external rather than internal cues. Such behavior occurs without awareness and the amount consumed is influenced by factors, such as portion size, the visibility of food, and the ease with which it can be obtained. Brunstrom (2011) noted that energy intake to a large extent depends on the size of the meal, something that is determined before we start eating. He makes the controversial suggestion that satiation plays a secondary role in the control of food intake: rather decisions about portion size made prior to eating play a predominant role.

Even if you accept that environmental factors are predominantly important our understanding of one these, portion size, is less than is often believed. What exactly can we say with any confidence about the influence of portion size on energy intake? What additional information do we need to establish?

Increasing Portion Sizes?

A "portion size" is the actual food that is placed on your plate, reflecting your own choice or the choice of the restaurant or food producer. It should be remembered, however, that in addition we need to know the amount consumed and any subsequent compensatory changes in the rest of the diet that may occur.

One thing that may appear to be uncontroversial is that the size of meals has increased over the years. Wansink and Wansink (2010) studied 52 of paintings of the Last Supper and found that over time the size of the meal had increased progressively. The size of the main meals grew by 69% between 1000 and the

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1700, whereas the bread grew by 23%. The greatest increases were observed in paintings between 1500 and 1900. There is no religious reason for this change, so it is likely to reflect popular perceptions of the size of meals at different stages of history. However, although an increase in portion size may have been taking place for hundreds of years, more recently there is a concern that the phenomenon has speeded up. However, even the statement that portion sizes have increased needs some qualification.

Nielsen and Popkin (2003) compared surveys of food consumption in the United States, paying attention to those foods that had been responsible for the greatest increase in energy intake; salty snacks, desserts, soft drinks, fruit drinks, French fries, hamburgers, cheeseburgers, pizza, and Mexican food. This list of foods represented 18% of the calories consumed 1977–1978 but 27.7% in 1994–1996. The portion size had increased for all these food items, with the exception of pizza, resulting over this period in an increased caloric intake being associated with each portion of food that was eaten. Piernas and Popkin (2011) looked specifically at changes in portion size in foods eaten by children and adolescents in the USA from 1977 to 2006. When the list of foods considered in the previous analysis was again considered, the age of the child was important, In 2003–2006 these food items accounted for 38% of the energy intake of those between 13 and 18 years but only 28% of those between 2 and 6 years of age. At all ages, a larger portion size of pizza resulted in a greater energy intake at meals at which they were consumed. In those aged between 7 and 18 years, more energy was consumed at meals that included larger portions of sugar-sweetened drinks, French fries, or salty snacks. The influence of portion sizes was not, however, uniform: for example, the energy from a meal of a pizza was greater in African Americans, Hispanics, and those from low household education homes. An increase in the daily energy intake (179 kcal/day) between 1977 and 2006 was found to largely reflect that more calories were eaten away from home. Over this period, the percentage of calories eaten outside the home increased from 23.4 to 33.9%.

Young and Nestle (2002) similarly considered ready-to-eat foods and found that portion sizes had begun to increase in the 1970s and were still increasing to the extent that most of the portions exceeded the government-recommended serving sizes. For example, a typical muffin in the United States is 333% greater than the USDA recommendation, and a serving of pasta 480 percent larger. They also found that newer editions of cookbooks suggested fewer servings for the same amounts of ingredients.

It was clear in the USA that the consumption of larger portion sizes in part reflected where food was eaten; in particular the trend to eat more often in restaurants. Between 1977 and 1991 there was a 75% increase in the number of restaurants in the United States (US Bureau of the Census, 1984, 1995). In particular, fast food restaurants offer cheap meals in large quantities (Harnack et al., 2000). It is perhaps not surprising that there are reports that the frequency of eating in fast-food restaurants is associated with a greater energy and fat intake, and a higher body mass index (BMI) (McCrory et al., 1999). Based on data from 29,217 children, from 2 to 18 years, Poti and Popkin (2011) argued that the location in which children eat influences their energy intake. In particular, foods prepared away from home have been largely responsible for the increase in the total intake of calories. They concluded that in the USA changes in where meals were eaten, and the sources of foods consumed at home, had fueled the increase in the energy intake of children.

Although a great deal of the evidence comes from the USA, a Dutch survey found a trend toward larger portion sizes and the introduction of multipacks (Steenhuis et al., 2010). However, in France a study of cookery books found that the portions suggested were 25% less than in the United States (Rozin et al., 2003). In fact, French portion sizes were smaller in restaurants, in supermarkets, and in "all you can eat" restaurants.

Although there is a common perception that portion sizes have widely increased, the reality is more complex and precludes a simple conclusion. In the United Kingdom, the Food Standards Agency (Church, 2008) examined the association between food portion sizes, energy intake, and weight gain. They found that there was no simple increase in portion size over time as much depended on the food item. They found that "larger portion size packs are available for many, often premium products, including luxury cookies, American muffins, luxury ice cream bars, sausages, premium crisps, and chocolate confectionery." But, in addition, smaller pack sizes were "available for many products (e.g., chocolate confectionery, savory snacks, soft drinks, ice cream cones, and bars) but usually as part of multipacks from larger retailers." The portion sizes of many products, such as biscuits and cakes, had remained fairly constant and there were only a few cases where there had been a general increase in size, for example, individual ready meals. This difficulty in making generalizations about portion size was demonstrated by Smiciklas-Wright et al. (2003) who found that over time about one-third of 107 commonly eaten foods had changed in size, with the majority having increased, although some had decreased in size. Importantly, there was no food that consistently differed in portion size for every age group and gender, making a generalization impossible.

Thus although there has been a trend for the portion size of various foods to increase, it is not universally the case Although larger packs of some foods are available, there has also been the provision of a wider range of the size of some items, for example, confectionary. In addition the choice of portion size can vary with age and socioeconomic background. However, as these data are mainly from the USA, there is a need to establish the situation in other countries. The worry, however, remains that the supersizing of food portions has changed our perception of the amount it is normal to eat.

Short-Term Responses to Portion Size in Adults

A tendency to eat more when more food was available was found by Pudel and Oetting (1977). They served people

from normal bowls to establish their usual intake and then substituted bowls that refilled from a hidden reservoir. Both those who were lean and those who were obese ate more than usual, although when told about the trick the lean, but not the obese, subsequently decreased their intake. On different days, Rolls et al. (2002) offered four different portion sizes of macaroni cheese and found that the bigger the portion size the more that was eaten: 30% more energy (162 cal) was consumed with the largest (1000 g) rather than smallest portion (500 g). Importantly hunger and satiety were similar after each meal and, in fact, only 45% of the subjects noticed that the portion size differed. In a restaurant, more pasta was eaten when larger portions were offered (Diliberti et al., 2004). Rolls et al. (2010) examined whether it was possible to use portion size to increase the consumption of vegetables when the amounts of meat and grain were kept constant. They found that an increase in the size of the vegetable portion size resulted in increased consumption. This tendency to eat more when served larger portions has been found regardless of individual characteristics, such as BMI, or a tendency toward dietary restraint or disinhibition (Rolls et al., 2002, 2004a, 2004b, 2007b).

Similar reactions to snacks have been reported. Wansink and Park (1996) gave people in a cinema either a medium or large bucket of popcorn. More was eaten by those given the large bucket. Similarly, an afternoon snack of potato chips (crisps) was offered on different days, consisting of various weights of the snack in the same sized bag. Both men and women ate significantly more when the portion was larger (Rolls et al., 2004b). Importantly, there was no difference in the chosen size of a subsequent meal; that is there was no reduction in energy intake to compensation for the previous high levels of consumption.

Levitsky and Youn (2004) gave students a buffet lunch and were told that it was a test of flavor enhancers and that they could eat any amount they liked. Later, they were served either 100%, 125%, or 150% of the amount previously consumed. With the larger servings, more food was eaten. The consumption of all foods on offer, soup, pasta, breadsticks, and ice cream, all increased significantly in proportion to the size of the serving. Surprisingly, the portion size can also increase the consumption of unpalatable items. When given a medium or large size serving of stale 14-day-old popcorn, 33.6% more was eaten from the larger buckets. Thus, an environmental cue had a greater influence than the taste of the food (Wansink and Kim, 2005), suggesting that the manipulation of portion size could be used to increase the consumption of nonpreferred healthful foods.

This type of laboratory or controlled real-world study has produced a reasonably consistent finding: food consumption increases when the portion size is larger. Such findings are the basis for the received wisdom that an increase in portion size plays a role in the increased incidence of obesity.

Yet, although consistent with such a view, such data require to be subjected to careful scrutiny. Such studies consider in isolation one aspect of the environment, portion size. The experimental design used has often emphasized the importance of portion size by removing the other information that we use in such situations. As such, the role of portion size may be exaggerated. However, although important in a laboratory paradigm, there is a need to establish the relative importance of such a phenomenon when placed in a wider social context. Is the effect similar with all foods? Does the increased consumption of a high level of a particular macronutrient have a differential effect over time? To what extent does age, sociobackground, the social context of eating, obesity, or restrained eating influence the response to portion size? We cannot simply conclude that portion size is a universally important variable without systematic study.

Unit Bias

Herman and Polivy (2005) suggested that norms concerning portion size may be influenced by both the amount served but also the number of items. Whereas the response to an amorphous food, such as macaroni cheese, reflects a reaction to the amount present, in other situations intake is influenced by the number of items consumed. For example, when sandwiches were offered, cut to different sizes on four separate days, significantly more was eaten when the portion size was larger (Rolls et al., 2004a). Such data may, however, reflect either an effect of overall portion size or alternatively the size of each food items if a norm of eating a particular number of items was influential. It is possible that consumption can reflect either the amount of food, or number of items available.

Marchiori et al. (2011) noted that much of the work in this area has considered portion size and there had been relatively little examination of the size of food items. Geier et al. (2006) placed Tootsie Rolls (a US brand of chewy candy) in bowls in a public area of an office. On alternate days these were of a small (3 g) or large size (12 g). Thus, the weight of available snacks was constant but the unit size varied. Similarly, in an apartment building, on some days normal sizes pretzels were on offer in a bowl and on other days the pretzels were similarly presented but they had been cut in two. In both cases, more was taken when the unit size was larger. The consumption of candy was also offered in its original size and when cut in two. Offering the half-size sweets halved the amount consumed. There was a cognitive bias that it was appropriate to consume a particular number of food items, regardless of their size. Similarly Geier et al. (2006) suggested that there is a "unit bias"; that is there a perceived appropriate number to eat when presented with a food in a particular form. When pretzels were presented half the normal size, even though there was available exactly the same overall amount, and there were no economic consequences associated with eating more, less was consumed.

It is easy to see that such a "unit bias" will encourage a higher consumption when larger unit sizes are presented. Such data suggest that in addition to using smaller portion sizes, smaller unit sizes may help to control consumption. The perception of the appropriate amount to eat will determine the amount served. It is apparent that portion size should not be exclusively

considered as on occasions the unit size, when portion size has remained constant, has been found to be influential.

Expected Satiety and Satiation

Brunstrom and Rogers (2009) examined the common assumption that it is the palatability of food that determines the chosen portion size with consequences for weight gain and obesity. They considered the relative role of palatability and "expected satiation" the ability to stave off hunger. When 17 foods commonly eaten for lunch were examined, they found that both the reward offered by the food item, and the portion sizes in kilocalories, were both closely associated with expected satiation. Foods that were not expected to result in prolonged satiation were chosen in larger portion sizes. Importantly, foods expected to produce a lower level of satiation tended to be more energy dense. They concluded that their findings questioned the role of palatability when choosing the size of a meal; in contrast "expected satiation" played an important role.

Many studies in this area have looked at preferred foods with unspecified portion sizes. Alternatively, the same weights of foods have been compared. However, it has been argued that when you wish to consider energy intake, you need to compare foods on a calorie for calorie basis (Brunstrom and Rogers, 2009). Is one calorie of food X more liked, satiating, or selected in higher quantities than food Y? Brunstrom and Rogers (2009) reported that foods that were expected to generate greater satiation were selected in smaller portions. High energy foods were consumed in greater amounts; but not because they were more liked, rather because it was anticipated that they would produce a lower level of satiation.

Thus a novel and interesting approach is the proposal that portion size is influenced by "expected satiation." The variable was measured by Brunstrom (2011) using psychophysical methods: essentially a standard food of known energy content appears on a screen and the size of a portion of a test food is manipulated until it is estimated to make you feel equally full or alternatively will stave off hunger equally well. Brunstrom et al. (2008) found that there was often a mismatch between the expectation of satiety, satiation, and the actual energy provided by a food. Some foods are expected to result in five to six times more satiation per kilocalorie than others. As an example, 200 kcal of pasta and 894 kcal of cashew nuts were expected to result in the same degree of satiation. In particular, foods of a high energy density and those high in fat were expected to offer a low level of satiation. It was found that there was a high correlation between familiarity with a food and the expected satiation, suggesting that the relationship is learnt, although it was not possible to rule out responses based on parameters such as the volume of a food.

These measures are good predictors of both the energy of the meal put on the plate but also palatability. Brunstrom and Shakeshaft (2009) considered the role played by "expected satiety" when deciding about portion size. With various snack foods, the portion size was found to be predicted by both the liking for the item and expected satiety. However, there were individual differences, with those with a higher BMI, and those who were restrained eaters, responding more to expected satiety. Importantly, although expected satiation and expected satiety are influenced by physical characteristics, for example, the volume, they are also learned. Brunstrom et al. (2010) explored changes in expected satiation as food became more familiar. For example, as subjects became more familiar with sushi, the expected satiation increased. They interpreted such findings as evidence of "satiation drift" that is foods are not believed to be very satiating until we learn otherwise. It was suggested that this may reflect an evolutionary advantageous response; time is not spent eating unfamiliar foods that were probably not too nutritious.

Such findings show that predispositions and knowledge about food, prior to its consumption, are important in our choice of portion size and this reflects learning and adaptation. As there is a commonly accepted norm that we should clear our plates, it is important that we further consider the psychological factors that determine the portion size that is chosen. Premeal planning has been reported to be the most powerful predictor of the amount consumed (Fay et al., 2011). These findings also illustrate that we should be cautious in assuming that portion size as such is the parameter to which we should direct our attention. Often the foods offered in larger portion sizes have a higher energy density, such that we need to establish whether we gain additional understanding from considering portion size rather simply examining energy density.

Energy Compensation?

Although there is considerable evidence from laboratory studies that increasing the portion size increases the consumption of many foods, it would be unwise to uncritically generalize from such data to everyday living. The laboratory lacks most of the relevant contextual information that normally influence what and when we eat. Even if a similar response existed in real world situations, we need to know whether it is a response that continues over time or whether adaptation occurs via changes in the other aspects of the diet. Essentially, having consumed a larger meal, does energy intake decline in subsequent meals? This is an important question as the answer determines the attention that should be directed to portion size. If having eaten more for one meal, you eat less during the next meal, then the importance of the portion size is greatly reduced. A transitory effect is of little practical significance.

Rolls et al. (2006) for two days gave adults main meals under controlled conditions and provided snacks for between meal periods. On three different occasions the same menu was provided with 100, 150, or 200% of baseline amounts being provided. Increasing the portion sizes by 50% resulted in 16% more energy being consumed and when the size was 100% greater the intake of energy increased by 26%. All aspects of

the meals, including the intake of snacks, increased when more was available.

There are various reasons to be cautious when interpreting this study. The meals were all eaten at scheduled times in private cubicles in a laboratory, such that the effect of portion size was maximized and other factors diminished. There was no choice of when or if you ate, or the nature of the meal. It is an obvious comment that energy compensation is most likely when you decide if and when you want to eat, and is more likely to occur when a choice of foods differing in energy density is provided. Rather than increasing the size of every component of a meal, an interesting question is what response would there be to a larger portion of a single component of a meal, both within a meal and subsequently. Finally, a study for two days may not be sufficient to allow counterregulatory mechanisms to express themselves (de Castro, 1996).

A later study by the same group, however, looked at the impact of larger portion sizes for 11 days and again reported that the increased energy intake was not compensated by a lower intake at a later time (Rolls et al., 2007b). Again, all food and drink was provided for two 11-day periods, when 100% or 150% of the portions of all items were provided, resulting in an increased daily intake of 423 kcal. In this instance participants were supplied with all meals, although only on nine days was the main meal consumed in the laboratory. Larger portion sizes resulted in an increased intake of most foods, including snacks. Although the authors claimed that the continued response to larger portions did not support the view that biological systems eventually adjust energy intake, the comments directed to the initial two-day study equally apply. The provision of meals of the same energy density with the instruction to consume three meals a day limits the opportunity for physiological mechanisms, should they exist, to exert an influence.

More generally Levitsky et al. (2005) considered the bodily response of normal weight adults to overfeeding. For 13 days, each subject consumed 35% more energy than at baseline with a resulting increase in weight of 2.3 kg. When they returned to their normal diet, although energy intake was similar to baseline values, subjects lost 1.3 kg of body weight. It appears that the amount eaten is not the only determinant of body weight and indicates a need to monitor more than energy intake when considering any response to changes in portion size. The general observation that although from time to time there are large variations in energy intake, adult body weight remains remarkably constant, suggests that weight must be regulated by biological mechanisms. Such observations illustrate the need to study the response to changes in portion size over an extended period and require more than a simple calculation of the energy consumed.

In fact, there are many reasons to question the generality and interpretation of longer term studies of portion size examined under laboratory conditions. For example, the time of day a meal is consumed may be important. There are reports that eating a larger, not smaller, breakfast is associated with a lower total daily energy intake. Based on 7-day dietary diaries, de Castro (2004) found that the proportion of energy eaten for breakfast was negatively correlated with the total daily energy intake, whereas eating more in the evening was positively associated with a higher daily intake. Thus there was the suggestion that when meals were freely chosen an adjustment in energy intake occurred within a day.

The amount eaten also varies with the day of the week, with more being consumed at weekends. De Castro (1996), based on seven-day dietary diaries, concluded that typically there are "periods of eating interspersed with periods of fasting": in the short-term the size of meals was elastic and appears to be unregulated to the extent that intake can vary within a wide range. However, physiological mechanisms appear to come into play after a delay of at least a day, and usually longer, such that the amount consumed one day reflects the intake two days previously. Such effects are more likely to be observed when the frequency of eating and the choice of food are under the control of the individual, rather than being imposed by the experimenter.

It should be noted, however, that the influence of the size of breakfast is a matter for debate. Schusdziarra et al. (2011), in contrast to the findings of de Castro (1996), observed that acute studies have not tended to find that a larger breakfast resulted in a smaller overall intake of energy, rather a larger breakfast was associated with a larger overall intake. In contrast, when the ratio of breakfast to overall energy intake was examined Schusdziarra et al. (2011) and de Castro (1996) were in agreement. However, the ratio of energy consumed at breakfast to total intake depended not on the size of the breakfast, but rather on what was eaten subsequently. The amount eaten for lunch and dinner was fairly constant but the amount eaten for breakfast differed with a resulting difference in the ratio. Therefore it was a smaller breakfast that was associated with a smaller total daily energy output.

A factor that has not been considered is the nature of the meal. There are reasons to suggest that macro-nutrient composition of the increased portion size may be influential. Holt et al. (1995) examined the ability of a range of foods to induce satiety over a 2 h period. The greatest satiety was produced by boiled potatoes and the least by a croissant. The level of protein, fiber and water correlated positively with resulting satiety, whereas the fat content was negatively associated. In the context of portion size, such data would lead to the prediction that the consumption of foods high in fat would tend not to lead to a reduction in energy intake, whereas other macronutrients might reduce subsequent intake. Consistent with the importance of the nature of the meal, Vozzo et al. (2003) compared the impact of preloads of the various macronutrients on spontaneous eating. Protein rather than carbohydrate and fat resulted in greater satiety and lower food intake. It was important that subjects were free to choose when and how much they ate.

Thus, the question arises as to whether the response to an increased portion size depends on the macronutrient composition of the meal. In addition there is a need for an examination of the long-term impact of changing portion size on energy intake and body weight. Simply these questions have been little considered.

Surveys of the Impact of Portion Size in Children

In the United States, the average portion size consumed by children under 2 years of age did not change from the 1970s to the 1990s (McConahy et al., 2002). Although, in contrast the portion sizes consumed by children older than 2 years, in particular drinks, had increased. An increase has also been reported with the most commonly consumed foods (Smiciklas et al., 2003).

McConahy et al. (2002) examined surveys of children aged 1–2 years of age and related portion size to energy intake and body weight and found that the average portion size was positively related to both. Later they similarly considered children aged 2–5 years and reported that the average portion size was the single best predictor of energy intake (McConahy et al., 2004).

In the United States, Fox et al. (2006) considered a random sample of children from 4 to 24 months of age. There was a negative correlation between the number of times that eating occurred and portion size. There was also a negative relationship between the energy density of the food and portion size. In younger children, less was eaten when the energy density was greater, although this did not occur in toddlers. They concluded that there was energy self-regulation in children of this age.

A relationship between energy intake and portion size has been found although such correlations are liable to different interpretations. Energy intake necessarily reflects factors other than portion size, for example, the frequency of eating and the energy density of the items consumed. Again many of these data reflect surveys of the amount eaten rather than the amount that could be potentially eaten: that is portion size was not recorded.

An exception was the study of Mrdjenovic and Levitsky (2005) who recorded the food intake of children 4–6 years of age, for 5–7 days. They found that the best predictor of the amount of a food eaten was the amount that was served, although usually the amount eaten was less than the amount served. However, again causality cannot be assumed as the child might have influenced the serving size by indicating how hungry they were, or they may have accepted or rejected the offer of a second serving.

Short-Term Responses to Portion Size in Children

It cannot be assumed that children necessarily respond to portion size in a similar manner to adults, given differences in their eating patterns. Although there are reports of a similar adult-like response to portion size in some children, age may be important. Fisher et al. (2003) considered children from 3 to 5 years who were given either an age-appropriate sized lunch or one double the size. A 25% increase in the energy intake from the experimental food item resulted, leading to an increased overall energy intake from the meal of 15%. In contrast, in a similar study a larger portion size increased the food intake of 5-year olds but not those aged 3.5 years (Rolls et al., 2000). In these studies, the ages of the children varied over a small range although Fisher (2007) compared those from 2 to 9 years. A macaroni meal was offered in an age appropriate size or double that quantity. The child's age did not influence the result; 29% more was eaten when the larger serving was provided. It was suggested that the response to larger portions was consistent across the age range although children younger than two years were not considered.

An interesting question is the extent to which any effect of portion size might interact with the nature of the food supplied. Is it only the intake of palatable food that is enhanced or would there be a similar response to less preferred items? Kral et al. (2010) considered this question. Children aged 5–6 years ate a pasta meal of a constant size with side dishes of different sizes on separate occasions. Doubling the portion size of apple sauce, that was described as sweet although it had not been sweetened, increased consumption by 43%. In comparison, increasing the amount offered did not raise the consumption of carrots or broccoli. Although it is unwise to place too much emphasis on a single isolated study, this failure to find an increased intake of vegetables immediately suggested that the portion size effect occurs with some types of food and not others. The question needs to be further addressed. The situation is, however, unlikely to produce simple answers as Spill et al. (2010) found that doubling the portion size increased carrot consumption by 47% when given to 3–5-year olds at the beginning of a meal.

Bite Size

Although there is evidence that portion size may influence the amount we eat there is also evidence that the portion size influences the way we eat. In children, aged from 2 to 9 years, Fisher (2007) examined the response to portion size of self-determined, age-appropriate, or double age-appropriate meals: the frequency and size of bites were determined. When given a large portion 29% more was consumed, a reflection of an increased amount per bite rather than an increased number of bites per meal. Although the mechanism behind the tendency to eat more per bite when given a larger portion the mechanism is unclear, it does seem to be a general tendency as it occurred irrespective of the age of the child. These findings were similar to a previous report (Fisher et al., 2003) that offering a portion, that was twice age-appropriate, increased the amount eaten by 25%, again a reflection of a larger amount consumed per bite. When children were offered age-appropriate sized meals, or double that size, an increased bite size resulted, even with children that did not consume more when a double-sized portion was offered (Fisher and Kral, 2008). They took a fewer number of larger bites per meal. Similarly in adults Lawless et al. (2003) examined the effect of increasing the size of a drinking vessel from 150 to 600 mL on the amount drunk and found that the volume of a sip increased by 15%. There is a consistent finding that larger portion sizes increase the amount taken per bite. Such findings raise the possibility that the use of cutlery that limits the amount of food that forms a single bite, for example, a smaller spoon, may be helpful.

Does Energy Compensation Occur in Children?

The examination of single meals has produced a fairly consistent picture but the important question is whether there are longer-term implications for total energy intake. Having eaten more at a meal what happens subsequently? In 5-year olds Fisher et al. (2007b) offered age appropriate or double sized portions at breakfast, lunch, dinner, and an afternoon snack. Being offered the doubled sized meals increased the energy intake from these items 23%, although the energy intake from other foods that were of normal size did not differ. There were, however, large individual differences in the response to differences in portion size, although these differences were not related to body weight. In this group the effect of portion size continued throughout the day and was not associated with a compensatory decrease in the intake of other food items.

However, there are inconsistencies in the literature. There are various reports that the serving size influences the energy intake of children (Rolls et al., 2000; Mrdjenovic and Levitsky, 2005). Yet, there are also earlier reports that children are able to regulate their energy intake (Birch and Deysher, 1985, 1986; Birch et al., 1989a, 1989b, 1991; Shea et al., 1992; Birch et al., 1993; Birch and Fisher, 1995). Given the frequency that these earlier reports have been replicated they appears to be a genuine phenomenon and we must look to methodological differences to understand the apparently contradictory findings.

As one example Birch et al. (1991) examined the 6-day dietary diaries of children aged from 2 to 5 years. Although the amount eaten varied greatly from meal to meal, the daily intake was relatively constant. They found that a higher energy intake at one meal tended to lead to a lower intake at the next. Mrdjenovic and Levitsky (2005) similarly found a negative correlation between the amount consumed at one meal and the amount consumed at the next. In Scotland Nielsen et al. (2008) examined the daily energy intake of a sample of children between 2.6 and 6.8 years. Within subject variability was 19.2%, almost twice the figure of 10.4% reported by Birch et al. (1991). They discussed other studies of the freely consumed diets of children and found variation between 16.1 and 28.7% indicating a wide individual variation in day to day energy intake. Two statisticians, Hanley and Hutcheon (2010), considered the observations that although individual meals are variable the daily intakes are relatively constant. They concluded that the "belief that young children have a strong physiological compensatory mechanism to adjust intake at one meal based on intake at prior meals is likely to be based on flawed statistical reasoning." They calculated the variability in the daily intake if there was no correlation between intakes at individual meals and found the resulting variability accounted for the data without needing to suggest compensation in energy intake.

Many of the earlier studies found that energy intake compensation occurred over time, when studied in a laboratory setting where the serving size and food on offered were controlled. In contrast in the Mrdjenovic and Levitsky (2005) study children received meals of different foods and portion sizes and the frequency of feeding varied. These more varied conditions were closer to real-life situations and allowed the importance of a range of external factors to influence food intake. One argument used by Birch et al. (1991) to support the view that children are able over time to regulate energy intake is that there is a negative correlation between the amount eaten at successive meals. However, the interpretation of such data was challenged by Mrdjenovic and Levitsky (2005) who had also found a negative, albeit weak, correlation between energy intake at successive meals. They argued that this negative correlation reflected the behavior of the caregiver rather than the child. Regression equations did not find that the previous meal influenced food intake at the next meal when the amount of food served was included in the analysis. Consistent with this analysis Ruxton et al. (1996) found that the amount of food eaten by children at breakfast did not influence the amount eaten subsequently. The energy intake of the children has also been found to relate to the number of snacks but Anderson (1995) did not find that children adjusted the energy content of a meal for the energy previously consumed as snacks.

Data that has been again cited as demonstrating an ability of children to regulate their energy intake is that they eat less when high energy density food are provided (Birch and Deysher, 1985, 1986). Again Mrdjenovic and Levitsky (2005) found that children ate more if the meal comprised foods with a low energy density. They also found that the amount of food offered by the caregiver was related to energy density. When the energy density was higher the serving size was less. However, when the serving size was controlled the differential response to foods of different energy density was eliminated.

Given the apparent inconsistency between the suggested self-regulation over time of energy intake and reports that the consumption of high energy dense foods increased caloric intake, Fisher et al. (2007b) examined this topic. Five- to six-year-old children, in 2 $\times$ 2 design, were given either 250 g or 500 g servings, each of which offered either 1.3 or 1.8 kcal/g. They found that the effect of portion size and energy density were independent but additive.

Three to 5-year-old children were served a lunch of a baked pasta entrée that offered either 1.2 or 1.6 kcal/g in either a 300 g or 400 g portion. The energy density but not the portion size significantly influenced energy intake (Leahy et al., 2007). The failure to find an effect of portion size was surprising and may have reflected the relatively small difference in size. This observation raises the important question, how large is large. At what point does the size of a serving induce changes in intake?

MECHANISMS

The mechanisms that underlie the response to portion size have been the subject of limited research, although a greater understanding would allow an informed response to any problem it creates.

Although it is not universally true, adults often report that they were aware of an increased portion size, something that was true irrespective of whether the food was eaten as a discrete unit such as a sandwich (Rolls et al., 2004a), as an amorphous food such as macaroni cheese (Kral et al. 2004), a drink (Flood et al. 2006), or even everything eaten over 2 days (Rolls et al., 2006). It seems that the offering of a large portion size sanctions an increased intake; it was not that the increased size was not noticed but rather that in some way it permits or encourages an increased intake.

Although adults seem generally aware of differences in portion size a similar awareness is often not apparent in children (Fisher et al., 2003; Fisher, 2007). Eating in the infant is primarily driven by the physiological and psychological cues associated with hunger and satiety (Weingarten, 1985). In contrast the adult is affected by environmental cues including the social context, time of day, and the palatability of the available food. As a child develops, it learns cultural conventions and develops the eating style of an adult (Birch, 1980; Johnson and Birch, 1994) that by 3–4 years of age is influenced by a range of environmental factors (Birch et al., 1987, Birch et al., 1989a; Birch et al., 1989b).

Visual Cues

The importance of sight is well illustrated by the finding that you eat more if the serving dish is on the table rather than left on the stove. When the serving dish was not on the table, women ate 20% and men 29% fewer calories (Payne et al., 2010).

Scheibehenne et al. (2010) served lunch in total darkness where half the subjects unknowingly received larger portions with the consequence that they ate 36% more food. However, this increased consumption did not influence reported satiety. Those who ate larger portion sizes in the light served themselves less dessert than those who ate regular portions, something not true for those who had eaten in the dark. It appeared that satiety was more related to visual rather than internal cues.

Eating in the dark rather than light resulted in a decreased ability to estimate the amount that had been consumed. The ability of a larger portion size to increase consumption was greater in the dark. Thus, it seemed that visual cues play an important role in stopping eating. Similarly, Wansink et al. (2005a), (2005b) concluded that "people use their eyes to count calories and not their stomachs" as they consumed more soup when, unknown to those who were eating, more soup was added to the bowl. At least in the short-term, visual cues provide stronger cues to stop eating than physiological mechanisms.

If portion size is influential then visual information is essential in our estimation of this phenomenon: but is it the actual portion size that is important in increasing intake rather than our perception of the portion size. In fact Raghubir and Krishna (1999) concluded that the eye can fool the stomach, perhaps not a surprising conclusion as the estimation of volume and the associated weight are complex calculations. Does the estimation of portion size depend on the way the brain processes visual information and in particular how it responds to the manner in which food is served? As it is usual to eat most of the food that you have yourself placed on the plate, any contextual cues that increase the portion size leads to a greater calorie intake.

For many years, psychologists have studied the size–weight illusion, also known as the Charpentier illusion after the French physician who first studied it. Essentially, a larger object is judged to be lighter than a smaller object when they are of the same weight. Clearly, if a similar phenomenon occurs with food then it could have implications for our reaction to a larger portion size.

The vertical–horizontal illusion reflects the tendency to concentrate on the vertical and to downplay the horizontal dimension. It has been found that the vertical height is used predominantly to estimate volume (Raghubir and Krishna, 1999). Wansink and Van Ittersum (2003) found that adolescents poured 88% more drink into short/wide rather than into tall/narrow glasses of the same volume. Similarly, experienced bartenders, when asked to pour 1.5 ounces of a spirit, poured 26% more into a short/wide rather than tall/narrow glass. This phenomenon was systematically examined by Raghubir and Krishna (1999): based on a series of seven studies they concluded that a taller container was perceived as having a larger volume and increased consumption. With a taller glass, a smaller volume was perceived to have been drunk and the satisfaction with the drink was less. They proposed a "perceived size-consumption illusion" in that before consumption the volume was seen as being greater but after consumption it was seen as being less. The taller glass is perceived as larger than it really is, however, when a drink is taken the evidence contradicts this initial expectation resulting in more being drunk (Raghubir and Krishna, 1999). In fact, this lowered perceived consumption resulted in increased consumption.

Those wishing to sell drink should use tall bottles and glasses as they are perceived as having a greater volume and more is drunk. Those wishing to control caloric intake should measure a serving (measure not pour) into a wider and shorter container. These factors are of importance as much of the literature has considered the response to serving a larger volume. In practice on many occasions it is the perception of the volume that drives choice.

The shape of an object also influences size estimation. In general, triangles are seen as larger than a circle or square of the same area; elongated objects are seen as larger; squares where the diagonal predominates are seen as larger than circles; increases in size tend to be underestimated (Krider et al., 2001). Necessarily, food products come packaged and the question arises as to whether the perception of portion size depends on the shape of the package. A study considered a student cafeteria where the same amount of cream cheese was offered in either a round or square container and found that the square container was perceived as larger. When on different days one of two shapes of container were available, it was found that 44% of

customers bought two tubs when only the round were available, compared with 21% who bought two when the square variety was offered (Krider et al., 2001).

The effect of the way a pizza is presented on the amount purchased has been examined. Giving a discount for a larger pizza risks underestimating the extent to which the size is greater than usual. When asked the price subjects were prepared to pay for a pizza of different sizes, it was found that they expected a greater discount when they were given the diameter rather than when they were shown actual pizzas. In fact, providing the area of the pizza resulted in the greatest suggested price, an approach not taken by those selling pizza. Two small pizzas were viewed as being of a larger size than a single pizza of the same area. A square pizza when viewed with a point at the bottom was viewed as having a larger size than a circle of the same area (Krider et al., 2001). An added complication is that round pizzas are sold in square boxes—to which do we respond?

Given that it is received wisdom that one factor that has driven the increased incidence of obesity is the increase in portion size, the evidence that the nature of the packaging and the shape of the food influence the perception of size are clearly important. What is less clear, as it has been little studied, is the extent to which differences in perceived size influence consumption. It has been reported that multiple items may be purchased if an item is perceived to be smaller than it is (Krider et al., 2001). Yet, if the experience of eating does not match the initial impression of the size of the food item, then more may be consumed (Raghubir and Krishna, 1999). The generality of such findings needs to be established.

Labeling

There is growing evidence that the nature of labels impacts on the response to food. Although many experimental studies have examined the response to portions that have been provided by the experimenter, in real life foods often come with names that have implications for their consumption: for example, they may be labeled as a "Luxury rich chocolate pudding" or "Low-fat French Fries." What effect does the labeling or the image created by advertising have for the selection of portion size and the amount consumed? Are some individuals more influenced by the nature of the labeling; for example, those who are obese. Alternatively, can labeling decrease the portion size chosen, for example, by clearly demonstrating the portion size?

Labeling and advertising claims are important as when one piece of nutritional information is given then various inferences are drawn, often inaccurately. For example, a low-fat claim tends to lead to the assumption that it is lower calorie (Wan sink and Chandon, 2006a, 2006b). A low-cholesterol food is assumed to be low in fat (Andrews et al., 1998). Schuldt and Schwarz (2010) reported that labeling a biscuit as "organic" leads to the implicit assumption that it was lower in calories and that they could be eaten in larger quantities. Whereas 3.68 organic biscuits were perceived as an appropriate serving it was only 2.76 with the conventional biscuit, albeit they were nutritionally identical. Raghunathan et al. (2006) found that when you label a food as "healthy" there is a lower expectation that it is going to taste good. They suggested that the attraction of unhealthy food is its unhealthy nature, as this equates with a better taste. As there is no simple relationship between the health implications of a food and its taste, this relationship owes more to expectation than rational analysis.

There is considerable evidence that when faced with an advertisement the information given is generalized to an extent that may be invalid (Andrews et al., 1998). Wansink and Chandon (2006a), (2006b) offered novel types of M&Ms (colorful button-shaped chocolate candies) with one of two labels: "New 'Low-fat' M&Ms" or alternatively "New colors of regular M&Ms." When the amount taken from a large container was weighed 28.4% more was taken when it was falsely believed that it was a low-fat version. This difference in labeling resulted in the consumption of 244 kcal as opposed to 190 kcal. The difference was greater when the low-fat variety was offered to those who were obese: the intake was 47% greater when reading the low-fat message compared with a 16% increase if you were not obese. There was also a significantly greater underestimate of the calories actually consumed when it was thought to be low fat.

Subjects were asked about a container of M&Ms or granola with labels that stated that they were either regular or low-fat (Wansink and Chandon, 2006a, 2006b); items chosen as they had a very similar energy density. The task was say what amount it was appropriate to eat during a movie and to estimate the calories in each container. A low-fat label increased the serving size that was reported by the subjects to be appropriate and it made people feel less guilty about eating. The supposed low-fat M&Ms were thought to contain 20% fewer calories and the low-fat granola 25% less; perceptions that increased the serving size by 21% for M&Ms and 18% for granola.

These findings were followed up by considering whether the low-fat designation was increasing the view of what was the appropriate serving size. Granola was offered with either the low-fat or regular label, but also the information that the amount presented offered two or one servings, or alternatively did not mention serving size. These bags of granola were consumed while rating movies. Again those who received the low-fat designated product ate more; 249 kcal when labeled low-fat compared to 165 kcal when described as regular. However, the serving size information only reduced overeating among guilt-prone normal weight consumers, but not among overweight consumers. However, the tendency to eat more when the food was described as low-fat disappeared when serving information was provided to those of normal weight. In contrast, those who were overweight ate more granola when labeled as low fat, irrespective of whether the serving size had been indicated. There was a general tendency for participants to under-estimate their caloric intake to a greater extent when the supposed low-fat alternative was consumed. Wansink and Chandon (2006a), (2006b) surveyed products on the market and concluded that if

the granola had been in fact low fat then 35% less fat would have been eaten, but in practice 33% more calories would have been consumed.

van Trijp and van der Lans (2007) noted the lack of comparative studies of the way that people in different countries respond to food labeling and that much of the limited literature on the topic was American. They examined the perception of consumers of yoghurt in Germany, Italy, UK, and the United States. The perception of the impact on health, the understanding of the message and its credibility, differed between countries. A health claim, rather than one related to taste, increased the perceived healthiness of the product and to a small extent added to consumer appeal. The literature is very limited but it appears that the nature of claims on the label influence the perception of a product although it may be necessary to consider different countries and subsections of society within a country. The possibility exists that the response to labeling may be culturally determined and hence there may be differential consequences for the choice of portion size.

There has been little examination of the impact of claims on portion size but it would be surprising if there was not a relationship. The report that a description as a "low-fat" product increases portion size supports this expectation (Wansink and Chandon, 2006a, 2006b), although the nature of claims have not been examined systematically. Raghunathan et al. (2006) similarly asked subjects to rate cheese crackers that were described as containing 11 g of good fat and 2 g of bad fat, the opposite proportions or an equal amount of each. The cracker with the greatest amount of bad fat was predicted to be the tastiest. In a second study Mango Lassi, an Indian drink, was assessed and was found to be more enjoyable when it had been portrayed as unhealthy. These findings question the impact of low-fat options. If low-fat is perceived as inducing a poorer taste, then when given the choice the high-fat alternative may be chosen. Similarly how "healthy smaller portions" are perceived needs to be examined. It cannot be assumed that smaller portions will necessarily be viewed positively and lead to less consumption.

The provision of calorie information in restaurants is a recent approach to giving the population the information they need to control energy intake. Roberto et al. (2010) studied the choice of food at a dinner were the menu had or did not have information about calories, or had in addition information about the daily caloric intake needed by an average adult: 14% fewer calories were eaten when they were mentioned. Having information about calories and the number required resulted in a lower intake than the other conditions. In a similar study Girz et al. (2012) found that calorie labeling influenced the food chosen by dieters but not those who were not dieting.

What does seem clear is that advertising and labeling will bring both a precise and explicit message and in addition an implicit message, that is a range of assumptions that often will not correspond with reality. We need to understand the implications of such messages, both real and imagined, for the portion size on offer.

Size of Packaging

The serving sizes of some items are prescribed by the packaging, for example, a can of soft drink. However, in other situations, for example, when bulk purchases are made, or a portion is taken from a serving dish, the amount chosen reflects a personal decision. One response to a widespread concern about large portion sizes, and their possible role in obesity, has been for industry to offer products in a variety of different sized packages. Presumably, such an approach assumes that the offering of food items in smaller quantities allows the consumer to exercise better self-restraint. However, the response to different sizes of packaging is not necessarily straightforward. In addition to how products are chosen, we need to appreciate how we respond to larger packages.

There are reports that the size of a container can influence the ability to estimate portion size. Yuhas et al. (1989) asked for estimates of the amount of food found in various containers. The estimates of solids tended to be better than liquids that, in turn, were better estimated than amorphous items. Also, it proved easier to estimate quantities from small containers. It may be important that a large proportion of the studies of portion size have been carried out using amorphous foods such as macaroni cheese, often in large quantities. The extent to which the portion size effect reflects the type of food item considered, and its packaging, needs to be further examined. Yuhas et al. (1989) did, however, find that a 10-minute training session greatly improved the ability to estimate quantities. Bolland et al. (1990) reported that training to estimate food quantities resulted in better performance immediately after training and one but not four weeks later.

Raynor and Wing (2007) examined the response to snacks provided in either large or small packages and in small or large amounts. Potato chips, cheese crackers, cookies, and candy were taken home and eaten over three days. Providing double the amount increased the energy consumed from snacks by 81%, although the size of the package was not significant. Similarly, as part of a weight reduction program, Raynor et al. (2009) considered the influence of offering foods in single-serving portions as opposed to larger volumes from which a serving could be taken. The foods were cereal, peaches, apple sauce and cheese. The energy consumed as these foods was 15% less when eaten as a predetermined portion rather than being taken from a bulk supply. The effect was, however, due to the consumption of cereal and apple sauce and not the consumption of peaches and cheese. However, the opposite has also been reported. Coelho do Vale et al. (2008) concluded that we more easily regulate consumption when larger package sizes are used. They suggested that large package sizes tend to induce a conflict between indulgence and the need to regulate intake. Thus, it was proposed that large rather than small package sizes can reduce the likelihood of consumption being initiated. Clearly, such inconsistent results demand further study.

There are mechanisms at play unrelated to appetite. A major disincentive to buying smaller packages is that better value is

offered when buying in bulk. A store may indicate the number of grams on offer for the amount of money paid. Inevitably, better value is offered by a larger pack. There can be little doubt that a major obstacle to the widespread purchasing of small portions is a desire for a bargain, the wish to obtain a good return for your money. In addition, larger packages may prove to be more difficult to control when extracting a serving.

Are bulk purchases necessarily better value? Chandon and Wansink (2002) looked at the records of purchases in food stores in France and found that both fruit juice and biscuits were repurchased sooner when they had been bought in larger quantities: the average daily consumption was 110% greater for juice and 92% more for biscuits. It is, however, unclear whether this increased consumption reflects bulk buying rather than a pre-existing greater liking for the product? In a second study, these researchers gave individuals either four or 12 packages of various foods and measured their consumption over two weeks. When provided in larger amounts, they were eaten on average 112% faster. This effect was, however, short-term and after the eighth day the rate of consumption was similar, albeit sufficient food still remained. It was suggested that this reduction in the consumption of food, when supplied in larger quantities, reflected both taste-satiation and also that the reduction in the stockpile made it less visually salient. Recently, stockpiled items have been reported to be visually more salient, in part because they take up more room and hence are more obvious (Chandon and Wansink, 2002).

Wansink (1996) examined the influence of the size of packaging by comparing the response to a full bottle of cooking oil and a bottle twice the size that was only half full. Thus, the amount present was the same but the size of the container varied. Twenty-three percent more oil was used when it came from the larger container. A similar study using spaghetti found that 29% more was used when it came from a larger container. He followed up these findings by examining the relative influence of the size of the container and the unit cost of the product, in this case either tap or the more expensive bottled water. With the relatively costless item, tap water, a larger container increased the volume poured by a non-significant 3%, although in comparison it was increased by 15% with the more expensive bottled water. The finding was interpreted as indicating that the response was not to the size of the container as such but rather to the perceived value of the item. The effect of the size of packaging did not occur when it did not have an implication for the perception of unit cost.

The suggestion was that it was the unit cost that was the driving mechanism rather than the size of the container. The importance of unit cost was confirmed in a third study where more cooking oil and cleaner were used when it was said to have been sold at a discount rather than full price. Thus, the size of packing influenced the amount used, irrespective of the amount of the product that was kept constant.

It seems that bulk buying increases consumption of many products as more is removed from a larger container. As many of these data have been driven by a marketing perspective, the interest is in a single food item. The broader question of the impact of buying in bulk on the overall diet has been ignored. Whether it matters if you eat more of one food item will depend on the impact on the overall diet and whether there is energy compensation resulting from a decrease in the consumption of other food items? Equally, although there may be a short-term response to bulk buying, it is unclear if it persists over time. Alternatively, satiation may occur resulting in consumption returning to baseline values or possibly declining further. It is an obvious suggestion that you can get too much of a good thing.

Plate Size

Wansink (2004) pointed out that the consumption of about 70% of calories involves the use of bowls, plates, glasses, or utensils such as spoons. There is clearly a great opportunity for the perception of a portion size to be systematically influenced by the nature of its presentation.

Klara (2004) noted that in the USA in the 1980s the typical dinner plate was 25 cm whereas in the 2000s it was 30 cm, an increase in area of 44%. A frequent recommendation is that the use of a smaller plate will help to contain energy intake, a suggestion offered in the United States by the National Institute of Health and the Department of Agriculture, Center for Nutrition Policy and Promotion. This presumption that a smaller plate is beneficial has, however, been subject to very little systematic study.

The size contrast illusion refers to apparent differences in the size of identical objects depending on the context in which they are placed. In this context, the size of the plate would be predicted to be influential. A group of nutrition experts served themselves with ice cream after being given a smaller or a larger bowl and either a smaller or larger ice cream scoop. The larger bowl resulted in a 31% increase in serving size and the larger scoop increased the serving by 14.5% (Wansink et al., 2006). If cough medicine was given using a larger spoon, the amount poured was 11.6% greater than recommended, yet they underdosed by 8.4% when using a medium-sized spoon (Wansink and van Ittersum, 2010).

However, on different days, Rolls et al (2007a) served the same lunch on plates of a different size and found it had no effect on energy intake. Shah et al. (2011) similarly compared the influence of a large or small plate on the energy consumed at lunch by those who were of normal weight or who were obese. In neither group did the size of the plate influence the energy consumed. It is unclear whether the nature of lunch, with a range of small items, influenced these findings. It is also unclear whether the same finding would have resulted if a main meal of a few components was considered. The only mildly supportive data come from Koh and Pliner (2009) who monitored the amount of pasta consumed by pairs of females when supplied with either individual or shared serving bowls. Those who shared a served bowl ate less although this effect only occurred when the food was eaten from small plates.

There is some evidence that the size of the serving spoon may be influential. Marchiori et al. (2011) placed a large bowl of M&Ms on the front desk of an apartment building. On some days, a spoon was used to obtain a serving and on other days a quarter-cup scoop was available with a volume four times that of the spoon: more was taken when the scoop was larger.

Although the use of small plates is widely believed to result in a smaller food intake, it is based on very little research and that which exists is mainly negative. A possible message is that this is not an area where individual factors, such as plate size, should be explored in isolated; general statements are unlikely to be valid. We need to know whether any effect of plate size depends on the social situation, the nature of the food being eaten, and the type of person being studied, whether for example, they are obese or restrained eaters.

DISCUSSION

There is growing evidence that appetite and energy balance are controlled by a complex network of physiological mechanisms involving the brain, gut, and tissue. As such, a great deal of effort has been directed to finding a drug that will control weight gain. However, the complexity and multifaceted nature of the biology associated with food ingestion, and the ability of the body to adapt, have made the biological approach to manipulating calorie intake less successful than had been hoped. Another more controversial approach is to see the obesity epidemic as "a normal physiological response to a changed environment, not in the pathology of the regulatory system" (Zheng et al., 2009). It is what is placed on the plate before anything is consumed that is important, after which the underlying biological mechanisms do what they were designed to do. What has changed is the environment in which we live although such a perspective must acknowledge that obesity is not inevitable as not all sections of society become obese.

Thus, the alternative perspective is that food intake is controlled more by external rather than internal cues: we should aim to modify the environment and our lifestyle. de Castro (1996) concluded that the meal size is elastic and governed mainly by psychological, social, and cultural factors rather than physiological mechanisms. The suggestion has been made that satiation plays a secondary role in the control of food intake: rather decisions about portion size made prior to eating play a predominant role.

Similarly, Herman and Polivy (2005) argued that although hunger and satiety have traditionally been examined when trying to understand how much we eat, in fact they play a small role. Rather, in industrialized countries, eating is controlled by a desire to avoid overeating such that we restrict intake, albeit we often fail to achieve the objectives we set ourselves. We have rules predating the meal as to how much we should eat in particular circumstances. However, the portion offered in a restaurant, or sold in the store, tends to be seen as an authoritative indication of how much should be consumed. There are, however, limits and if the portion is clearly too large or too small, then it can be modified by leaving some on the plate or taking another serving. There is, however, no doubt that there is a fairly wide range over which we are prepared to see a portion as acceptable, although attention has been directed to a particular normative problem, "portion distortion," that is the recent tendency to see a larger portion as normal and desirable. Schwartz and Byrd-Bredbenner (2006) established the portion sizes of various foods selected by young adults and found that they were significantly larger than they had been 20 years previously. An inability to recognize an appropriate portion size is an obvious barrier to controlling food intake, those factors that influence the development of these norms need to be established. "Portion distortion" will be difficult to address as the appropriate intake will differ from person to person such that no universal advice can be offered.

This normative perspective is useful in interpreting the results of laboratory studies in which eating takes place in the absence of many usual sources of information. Placed in a situation where you are looking for indications of what is the appropriate portion to place on the plate, in the absence of alternative information the amount of food provided offers an important clue. As such, the response to the amount of food provided is going to be amplified, such that the response may be larger than would occur in more normal situations. In addition, Herman and Polivy (2008) made the distinction between normative cues, such as portion size, and external sensory cues such as palatability. They proposed that whereas normative cues affected everyone, sensory cues were more influential in some individuals, possibly the obese. In fact, Herman and Polivy (2007) suggested that one route to obesity involved sticking to norms that restricted intake when it was unclear how much it was appropriate to eat. In such situations, the environment is searched for indications of an appropriately sized meal and reliance is placed on arbitrary criteria such as the portion size. The risk is that this could lead to overeating while it was believed, falsely, that the intake was appropriate.

Future Research

The single most important objective is to establish the importance of portion size relative to the range of other variables that influence food intake. There is a need to establish that varying portion size does not lead to compensatory changes at either a psychological or physiological level. Although the portion size of many food items have increased, and laboratory studies find that more is eaten when more is on offer, this does not establish the real world importance of the phenomenon. Although for many such a relationship appears very likely, it should be remembered that the association has not been demonstrated. There is an urgent need for intervention studies that show that changing portion sizes reduce weight in those consuming a freely chosen diet, rather than in those in a laboratory situation that prescribes or limits the nature of consumption. Without such data, we cannot be sure that the response to portion size is more than a laboratory phenomenon of limited practical significance.

The relative importance of portion size needs to be established. Does it play a predominant or peripheral role in the development of obesity? Duffey and Popkin (2011) examined the relative roles played in energy intake by the energy density of food, portion size, and the number of times you ate or drank a day. All three factors were found to have contributed to changes in energy intake over a 30-year period. "Between 1977–1978 and 1989–1991, changes in portion size accounted for an annual increase in the daily total energy intake of nearly 15 kcal, whereas changes in the number of eating occasions accounted for an increase of just 4 kcal. By contrast, between 1994–1998 and 2003–2006, changes in the number of eating occasions accounted for an annual increase in daily total energy intake of 39 kcal, whereas changes in portion size accounted for an annual decrease in daily energy intake of 1 kcal." Such data put portion size into context. Since 1994, the increase in eating opportunities, rather than changes in portion size, were found to be responsible for the increase in energy intake. The finding of Brunstrom and Rogers (2009) that larger portions of foods were chosen when they were perceived to produce low satiation is also relevant; particularly as high energy density and low satiation were related. Is portion size adding anything to the approach of concentrating on energy density?

Whereas most studies have examined only one aspect of a food, necessarily in a real world situation many dimensions interact. Devitt and Mattes (2004) are unusual in that they considered the interaction between the unit size of food and its energy density. On four different days, food was supplied for breakfast, lunch, and the evening meal. High energy density foods were associated with a greater caloric intake irrespective of the form of presentation. It is unclear whether the failure to find an effect of the unit size of the foods reflected the study of the entire day in the real world, rather than one food item in the laboratory. The nature of the foods, omelette, wraps, and pizza, and the possibility for caloric compensation, may have been influential. Raynor and Wing (2007) asked whether the increased consumption associated with large portions reflected the greater amount of food available, rather a change in the unit size of that food. Again, subjects who regularly consumed snack foods were monitored going about their everyday lives. They were randomly placed in groups that received either large or small amounts, in either smaller or larger unit sizes. When given 100% more food, energy intake increased by 81%. The unit size, however, did not influence the amount consumed.

The microstructure of meals needs to be considered. How does offering a small portion of one food item influence the choice of accompanying items and the nature of future courses? Does, for example, eating a small first course increase the likelihood of eating a rich dessert? What is the net effect? With particular foods and with particular types of individual at what point does a small portion lead to the taking of a second serving? It is unlikely that everybody will respond similarly to a given portion size, it will for example depend on gender and the existing weight and activity level of the individual. As such, there is not likely to be one ideal portion size; one size will not fit all.

However, hopefully a relationship between portion size and obesity can be demonstrated, as such an association will offer the means of intervening to decrease energy intake. If so, a range of questions will need to be addressed.

It is likely that the influence of portion size will depend on the interaction between many variables: thus future research should consider portion size in a wider range of situations to establish the generality of its influence. Such variables will at the least include the social situation, packaging, advertising, labeling, the type of food and the attitudes, knowledge, and motivation of the individual. Rather than expecting a general reaction to portion size, any response is likely to interact with many factors. The considerable attention that has been given to portion size should not result in its importance being assumed. Palatability (Yeomans et al., 2001), the variety of available foods (Norton et al., 2006), whether the serving dish remains on the table (Payne et al., 2010), the number of people present (de Castro and Brewer, 1992), cognitive distraction (Brunstrom and Mitchell, 2006), and individual differences such as the degree of restrained eating (Herman and Mack, 1975) play a role.

If the approach is to have an impact, a major question that must be addressed is how can we generate widespread changes in portion size? It is perhaps unreasonable to expect a commercial organization to act independently when this may not be in their financial interests. There may be no alternative to government initiatives aimed at generating universal changes, although such is the diversity of the food and restaurant industries that this will raise substantial practical, commercial, and political problems.

The existing norms about the portion size of a range of food items needs to be established and the variables that influence differences in these norms should be examined. Do these norms vary, for example, with age, gender, socioeconomic background, education, or obesity? Such norms are likely to vary from country to country and food to food. Although to date most attention has been focused on energy-dense foods, the impact on other foods such as fruit and vegetables should be established with the aim of increasing consumption. Any differential response to intermeal snacks and meals needs to be examined.

The factors that lead to "portion distortion" should be established. What leads individuals to see a large amount of a food as being appropriate to eat? Is it possible to reduce such perceptions?

More specifically, the effect of portion size is not apparent in infants. The factors that influence the development of the phenomenon need to be examined with the aim of establishing an optimal behavioral pattern for the control of body weight. The extent to which the nature of adult intervention at mealtimes leads to children ignoring their internal cues should be established.

The influence of not only the food but also its packaging, labeling, and advertising needs to be considered. For example, what is the influence of buying in bulk? Is the serving portion increased or alternatively does the purchase of a large number of smaller items reduce or increase consumption? For a particular

food, is there a point at which the portion size is both acceptable and associated with reduced consumption?

What is the influence of labeling a particular portion size in a particular way? Irrespective of the actual portion size, how does the way it is described influence its consumption? Does a portion described as smaller and healthier result in an increased or decreased level of consumption? Given the reports that the label low-fat results in increased consumption (Wansink and Chandon, 2006), and the label healthy results in an assumption that it does not taste good (Raghunathan et al., 2006), similar responses may prove to be factors critical to the success of any attempt to reduce a portion size. The response of restrained and unrestrained eaters may differ. We need to establish that the response to a description of a small portion size is not to increase consumption of that item, or another component of the meal. Similarly the size and shape of the packaging will influence the way a food is perceived and the response needs to be established. Does packaging something so it looks more than it actually is lead to decreased consumption or alternatively disappointment and additional consumption?

The response to advice that has been given in different ways needs to be considered. Portions given in grams may be difficult to understand and it may be the exception that the trouble is taken to use scales. The use of standard measures may prove more useful but again people may not often be prepared to take that additional trouble. The impact of training people to recognize portions, perhaps using measures of everyday objects such as the size of a golf ball, could be examined. Pictures may prove to be more useful than giving the weight. In general, there is a need to establish to what extent the portion chosen relates to the suggested serving size on the packet.

Finally, there is a general need to consider individual differences in the perception of the appropriate portion size and to establish the actual portion size needed by an individual for weight control. These are likely to differ with age, gender, obesity, dietary restraint, education, social background, and individual differences in bodily size and life-style and hence caloric need.

The Value of the Portion Size Approach

Assuming that future research leads to the conclusion that the response to an increased portion size is increased energy intake and an increased incidence of obesity, can this insight be used to reduce the amount we consume? No easy or universal approach suggests itself. It is possible to imagine that a parent on a one to one basis might use such an approach with their child, but to seriously address the obesity problem we need interventions on a grander scale. In many situations, portion size is influenced by the decisions of multinational food producers or restaurant chains. It is in the nature of such enterprises that they are driven by the desire for profit, such that they are not going to want to act in a manner that puts them at a competitive disadvantage.

In this context, Herman and Polivy (2005) concluded that the jury was still out as there is a desire for value for money that was likely to lead to smaller portions being unacceptable. Supporting this view, Vermeer et al. (2010) used focus groups to establish views concerning the portion size of food items. There was a general perception that the portion size of many items had increased to a level where they were larger than was acceptable. However, most still saw "value for money" as important and that a larger portion was better value. Consistently, the groups were resistant to a reduction in portion size although they approved of a greater range of sizes being offered.

At a practical level, various approaches have been suggested to be helpful although there are no easy solutions. The individual could reduce the portion size by weighing all foods; something that is unlikely to occur widely other than during a period of dieting. Prepackaged individual servings could be sold, although whether they would survive the better value offered by buying in bulk is uncertain. It has been suggested that this problem could be addressed by an appropriate pricing strategy that did not make larger packages more financial desirable. Again, it is unclear how this could work. The additional packaging costs associated with many small items push up the cost. The alternative would be to increase the cost of a bulk purchase to ensure that there was no financial incentive to purchase. Customers are not likely to welcome such an increase in cost. To date, the most common approach has been to offer a range of portion sizes and in this way the consumer gets to choose, albeit they get poorer value if they choose a smaller portion size. Equally, the response to a smaller portion may not be what is intended. Perhaps, a second serving is taken or an initial smaller portion is then used to justify additional consumption of other items.

Another straightforward approach involves clearly indicating the intended portion size. For example, it is made clear that the package serves four. Again, there is a potential problem if the suggested serving conflicts with pre-existing expectations. The risk is that the product gets a bad name; a reputation for offering smaller portions than its competitors. In a free market economy, it is difficult to see how portion sizes can be consistently and universally modified. It would be unreasonable to unilaterally expect one firm to change their portion size. Unless their competitors do the same, they would be at a competitive disadvantage if value for money is perceived to be less. In addition, products are individual in nature making a general legal prescription difficult to draft and depending on your political perspective perhaps not an acceptable approach.

The review of the UK Food Standards agency commented that: "a causal relationship between increasing portion size and obesity rates would be difficult to establish, owing to the many confounding factors". It is difficult to disagree with this assessment. Even if portion size is influential during a single or a few meals, does it offer a practical means of intervening over the longer period? The interest in portion size reflects the increased incidence of obesity and will ultimately only prove to have value if it results in a practical and successful means of intervening.

Such interventions will need to be demonstrated to be beneficial in well controlled long-term trials.

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